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Observing the Global Water Cycle from Space

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1. THE GLOBAL WATER CYCLE

Although there is considerable water on Earth, only about 2.5% is in the form of fresh water. Of the fresh water, ~69% is unavailable as it is locked in permanent ice and snow, ~30% is stored in ground water, and only the small remaining amount is available in lakes, rivers, etc. (Table 1). The distribution of fresh water is highly uneven over the Earth, with both strong latitudinal distributions due to the atmospheric general circulation, and even larger variability due to landforms and the interaction of land with global weather systems.

Table 1. Distribution of water on Earth (Gleick, 1996)

	Volume	Total Water	Fresh Water
	(10^{15} m^3)	(%)	(%)
Oceans seas & bays	1338	96.5	--
Ice caps, glaciers & permanent snow	24	1.73	68.7
Ground water (fresh)	10	0.76	30.1
Ground water (saline)	12	0.93	--
Soil moisture	0.016	0.001	0.050
Ground Ice & Permafrost	0.300	0.022	0.860
Lakes (fresh)	0.091	0.007	0.260
Lakes (saline)	0.085	0.006	--
Atmosphere	0.013	0.001	0.040
Swamps	0.011	0.001	0.030
Rivers	0.002	0.000	0.006
Biological water	0.001	0.000	0.003
Total	1386	100	100

The annual global fresh water budget (Chahine, 1992; Gleick, 1996) is largely a balance between evaporation, precipitation and runoff. Although the available volumes of fresh water are small, the movement of fresh water through evaporation, atmospheric transport, precipitation and runoff is considerably larger (Table 2), due to the short residence time of water in these fresh water reservoirs. With a total atmospheric water store of ~13*$10^{12}$$m^3$, and an annual flux of ~460*$10^{12}$$m^3$/y, the mean atmospheric residence time of water is ~10 days. River residence times are similar, biological are ~1 week, soil moisture is ~2 months, and lakes and aquifers are highly variable, extending from weeks to many years.

Table 2. Land-ocean gross water budget. The flux estimates are from Peixoto and Kettani, (1973) and Baungartner and Reichel, (1975)

	Land Water Budget	Ocean Water Budget
	(10^{12} m^3 / y)	(10^{12} m^3 / y)
Evaporation (ocean)		-361 to -424
Evaporation (land)	-62 to -71	
Precipitation (ocean)		324 to 385
Precipitation (land)	99 to 111	
Runoff	-37 to -40	37 to 40

The potential for redistribution and acceleration of the global hydrological cycle has been hypothesized (Hornberger, 2001 and others) to be associated with global warming and anthropogenic modification of the climate system. Additional pressure is placed upon water resources by the burgeoning human population, the variability of weather and climate, and concerns about anthropogenic impacts on global fresh water availability.

2. OBSERVATIONAL REQUIREMENTS

This paper presents an approach to measuring all major components of the water cycle from space. The goal of the paper is to explore the concept of using a sensor-web of satellites to observe the global water cycle. The details of the required measurements and observation systems are therefore only an initial approach and will undergo future refinement, as their details will be highly important.

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